Darsgah-e-ahlebait

Journal of Biotechnological Sciences
ISSN: 2308-0043

Emam and Rady V-3-I-1 (2015)

Response of some canola (*Brassica napus* L.) genotypes cultivated in a newly reclaimed soil to plant distribution systems

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Keywords: Canola, Genotypes, New reclaimed soil, Plant densities.

Abstract

Two local and two imported canola genotypes were evaluated for their response to three of plant population densities during the two successive seasons of 2010/2011 and 2011/2012 at the Experimental Farm of Faculty of Agriculture, Fayoum, Egypt. The experimental arrangement was split-plot in a randomized complete block design with three replications. Canola genotypes were a main factor, while sub-main factor was plant distribution systems. Results showed that growth traits (plant height, height to the first lateral branch, number of branches and pods plant^{-1}) and yields and their components (seed yield plant^{-1}, biological, seed, oil and protein yields per hectare, 1000-seed weight and the percent of oil and protein) were positively affected by genotypes and/or plant distribution systems. The P_1 (35/9) genotype (a local genotype) was recorded the highest values of all growth, yields and yield attributes in both seasons. The plant density of 222 222 positively reflected in growth, yield and yield attributes over two growing seasons. Therefore, P_1 genotype with the plant population density of 222 222 (15 cm in both rage sides) could be recommended to obtain highest yields and yield attributes under a newly-reclaimed soil.

Introduction

Canola (*Brassica napus* L.) is one of the major oilseed crops, produced on more than 31 million hectares worldwide (Grant et al., 2012). It ranks only behind soybean and palm oil in global production (Francois, 1994). The canola quality, referring to cultivars that have been selected to produce an oil containing less than 2% erucic acid and a solid portion of the seed containing less than 30 µmol of range of glucosinolates, per gram of air-dry, oil-free solid (Anonymous, 2009). The ratios of unsaturated and saturated fatty acids in canola, with a density of 0.91 g/cm^3 are 93% and 7%, respectively (Dmytryshyn, et al., 2004). The combinations of unsaturated fatty acids contain 61% monounsaturated oleic acid, 11% linolenic acid and 21% linoleic acid (Izquierdo et al., 2003).

In Egypt, canola has been introduced recently as a promising new vegetable oil crop, especially in the new reclaimed lands (Nadia Gad, 2010). Canola has a bright future to contribute in reducing oil deficiency gap between production and consumption of edible oil. This wide gap between the production and consumption of edible oils reached about 90 % (FAO Statistic Yearbook, 2010). Growing canola oil crop in less fertile and/or salt affected soils may become successful if it could produce a relatively high economic yield with low level of inputs mainly nitrogen fertilizer (El-Howeity and Asfour, 2012).

Plant distribution system in a field has a great effect on the efficiency of plant canopy for light trapping and solar energy. The efficiency of conversion of solar energy into biomass by a plant is usually represented by a synthetic value which is the conversion efficiency of intercepted radiation or radiation use efficiency (Monteith, 1972). Plant distribution system depends on row spacing and/or plant distance within row

which produces different plant densities per unit area (Emam, 1999). Plant density varies considerably worldwide, depending on the environment, production system and cultivar, therefore, optimum density for a crop should be environmentally determined by a local research. Many researchers tested a wide range of plant densities in many countries. The plant densities ranged from 67 500 to 127 500 plant ha^{-1} (Momoh and Zhou 2001) in China, 74 074 to 222 222 plant ha^{-1} (Yousaf et al., 2002) in Pakistan, 200 000 to 1 300 000 (Al-Barzinjy et al., 2003) in Denmark, 148 148 to 1 333 333 plant ha^{-1} (Ozer, 2003) in Turkey and 650 000 to 950 000 plant ha^{-1} (Mobasser and Ghadikolaee, 2008) in Iran.

For any plant distributions, increasing plant density (increasing number of plant per unit area) was occurred by decreasing the distance between rows and/or between plants as well as increasing seed rate. Plant height, height of the first branch and biological yield ha^{-1} were increased by increasing plant density (Al-Barzinjy et al., 2003; Keivanrad et al., 2012 and Naseri et al., 2012). While, number of branches per plant, number of siliquas per plant, 1000-seed weight and seed yield per plant were decreased by increasing number of plants per unit area (Momoh and Zhou 2001; Al-Barzinjy et al., 2003; Kazemeini et al., 2010; Lack et al., 2011; Keivanrad et al., 2012; Naseri et al., 2012 and Champiri and Bagheri 2013).

Seed yield ha^{-1} was non-linearity responded to plant density. Where, increasing number of plants per unit area up to 110 plants m^{-2} (Al-Barzinjy et al., 2003), up to 80 plants m^{2} (Mobasser and Ghadikolaee, 2008) and up to 60 plants m^{-2} (Naseri et al., 2012) increased seed yield, but farther increase in plant density was decreased seed yield. While, Yousaf et al., 2002; Faradonbeh et al., 2011; Mousavi and Bagheri 2011; Keivanrad et al., 2012; and Saeedi et al., 2013 found that decreasing number of plants per unit area increased seed yield ha^{-1}. In general, seed oil and protein percentage were not responded to plant density (Al-Barzinjy et al., 2003; Ozer 2003 and Saeedi et al., 2013). While, Lack et al. (2011), Keivanrad et al. (2012) and Naseri et al. (2012) mentioned that increasing plants per unit area was negatively affected seed oil percentage.

However, there are little published research data on the plant density or row spacing response of canola in Egypt, the present study aims at declaring the influence of plant distribution systems on growth, yield and some yield components of some genotypes of canola under the conditions of newly reclaimed soil at Fayoum governorate, Egypt.

Methodology

Two field experiments were conducted in two successive seasons (2010/2011 and 2011/2012) in the Experimental Farm of the Faculty of Agriculture, Fayoum University, Southeast Fayoum Governorate (29° 17'N; 30° 53'E), Egypt to evaluate the effect of different plant densities on plant growth, yield and yield attributes as well as seed quality of some canola genotypes under the adverse conditions of a new reclaimed soil in Egypt.

Initial analysis, for some physical and chemical properties of the Experimental soil, was performed and obtained data are presented in Table (1). Analytical procedures were those recommended by Wilde et al. (1985). The Experimental soil was loamy sand with above neutral reaction

A randomized complete blocks design, spilt–plots with three replicates, was undertaken where the genotypes laid out in the mean plots and plant density in the sub plots. The plot area was 10.5 m^2 contains 5 rows, with 3.5 m long and 60 cm apart. The treatment used were canola genotypes P_1 (35/9), P_2 (26/18) P_3 (Drakkar) and P_4 (Hanna). These divergent genotypes have been screed as different salt tolerant by Afiah et al. (1999) and confirmed by Sharaan and Ghallab (2002). Their origin and pedigree are shown in Table (2). Plant distribution systems were 5 and 10 cm in one rage side and 15 cm in both rage sides alternatively. The plant distributions were produced plant population of 333 333, 166 666 and 222 222 plants ha^{-1} for 5, 10 and 15 cm, respectively.

Twelve treatments were set up with three replicates (a total of 36 plots). Calcium supper-phosphate (15.5 % P_2O_5) at the rate of 475 kg ha^{-1} was added before ridging. N fertilization was applied in the form of ammonium sulphate (20.5 % N) at the rate of 178.50 kg N ha^{-1} in three equal doses (with the 1st, 2nd and 3rd irrigation). The preceding crop was pepper (*Capsicum annuum* L.) in the first season, while sesame (*Sasamum indicum* L.) was the preceding crop in the second season. Canola seeds were sown on 8 and 12 November in the first and second seasons, respectively in hills spaced according to the treatments. Each plot was irrigated separately. All other recommended agricultural practices for canola seed production were adopted throughout the growing seasons; 2010/11 and 2011/12 according to the bulletin of Egyptian Ministry of Agriculture (712/2001).

At maturity, random sample of 10 guarded plants was taken from each plot to determine the growth traits (i.e., plant height, height to the first lateral branch, number of branches and number of pods $plant^{-1}$). The plants of each plot were taken to determine biological and seed yields ha^{-1} as well as oil and protein yields ha^{-1}. They were estimated by multiplying the oil or protein percent by seed yield ha^{-1}. Seed oil and protein percent were measured by Near Infrared Analyzer (Granlund and Zimmerman 1975).

Data obtained for canola plant growth and yield at harvest were statistically analyzed, according to Gomez and Gomez (1984), and the least significant difference (LSD), at a probability level of 5%, was used to compare the obtained data.

Results and discussion

Data shown in Table 3 indicate the analysis of variance, which reveal that there were significant ($p = \leq 0.05$) or high significant ($p = \leq 0.01$) differences among the plant genotypes in all of the studied traits in both cultivation seasons. Seed yield per plant and per hectare and protein yield per hectare were the parameters that showed high significant ($p = \leq 0.01$) differences among the plant genotypes in both 2010/2011 and 2011/2012 seasons. These differences are doubtless attributed to the genetic build up of the different genotypes under investigation. In addition, the experimental treatments such as the plant distribution systems may be contributed to some extent to these differences among the studied genotypes. Interaction of the crop genotypes and the applied plant densities showed significant ($p \leq 0.05$) differences for most of the investigated traits over both seasons.

Results of this study for plant growth components and some yield attributes are presented in Table 4. Growth traits (plant height, height to the first lateral branch, number of branches and number of pods $plant^{-1}$) showed variations between the genotypes. Except the height to the first lateral branch, the genotype P_1 (35/9) showed the highest values of growth traits compared to all other genotypes in the 2010/2011 and 2011/2012 seasons. The effect of population density/spacing between or within rows was highly significant ($P \leq 0.01$). Although recorded reduced plant height and height of the 1st branch, the treatment of D_3 (15 cm between rows and the planting in both rage sides) found to be the best for number of branches/plant, number of pods/plant and seed yield/plant over both growing seasons. The interactions between genotypes and plant population densities are significant ($P \leq 0.05$) or highly significant ($P \leq 0.01$) in both seasons, except the height of 1st branch and number of branches per plant, which showed non-significant values in 2010/2011 season. It is seems that plant (in D_3 treatment) reduces its height and height of the 1st branch by affect the internodes growth may be through the control of gibberellin hormone synthesis. Here, we suggest that the plant density of 222 222 plants/ha led to reducing the plant height by affecting the internodes growth, while increased the number of branches/plant by negatively affecting the apical meristem. The increase in number of branches/plant in D_3 density may be also due to that plants received sunlight easily and penetrating the light into below parts of plants that cause to transform auxin hormone from apical meristem to the sites-forming lateral buds to increase plant branching. Consequently, the increase in the number of branches/plants contributed to the increase in number of pods/plant and seed

yield/plant. Fathi (2008) mentioned that number of branches reduced with increasing plant density and attributed this finding to stimulating the apical meristem more than side meristems. The same result was obtained by Ozoni Davaji et al. (2007). They indicated that favorable number of branches yielded in two ways; low population density causes to increase number of branches, in contrary high population density causes to reduce the number of branches, yielding desired number in low population densities of canola plants constrained by thin canopy that is more sensitive to growing weeds than high population density. Under undesired environmental conditions, it is possible that plant population reduce so that increasing branches can't compensate loss of plants, on the other hand, under desired environmental conditions canola produce branches so much that stem isn't able to holding them and lodging would occur and harvesting would difficult (Omidi et al., 2004).

Results of yield attributes are presented in Table 5. Yields and their components (biological yield per hectare, seed yield per hectare, oil yield per hectare, protein yield per hectare, 1000-seed weight, oil% and protein%) showed significant ($P \leq 0.05$ or $P \leq 0.01$) increases with P_1 (35/9) compared to all other genotypes (P_2, P_3 and P_4), while revealed less values with P_3. These results are in accordance over two seasons (2010/2011 and 2011/2012). Except some fluctuations, the effect of population density/spacing between or within rows was highly significant ($P \leq 0.01$). The treatment of D_3 (15 cm between rows and the planting in both rage sides) found to be the best, where recorded the highest values ($P \leq 0.01$) for seed yield/hectare, oil yield/hectare, protein yield/hectare, oil% and protein% over both growing seasons. The interactions between genotypes and plant population densities are significant ($P \leq 0.05$) or non-significant in both seasons, where 1000-seed weight and protein% revealed significant values in 2010/2011 season and protein yield/hectare and 1000-seed weight recorded significant values in 2011/2012 season. The superiority of P_1 among all tested genotypes may be attributed to its vigorous growth (Table 4) and to its population density. It also seems that D_3 distribution allows sunlight to penetrate and absorb by plants, resulting in the increase in the biological yield and all yield attributes. Ozoni Davaji et al. (2008) reported in a study on canola that the density of 67 plant/m^2 yielded highest dry matter among all used densities (33, 67 and 133 plant/m^2). On the other hand, the present study showed that the density of 222 222 plant/hectare yielded highest growth and yield attributes among all tested densities (333 333, 166 666 and 222 222 plants/hectare; Tables 4 and 5). This suitable plant population density enabled plants to take advantage from the growing environment and other sources and also reduced the competition among growing plants. The highest seed yield obtained from P_1 genotype compared to all other genotypes may be attributed to the difference of genotypes contributed to their genetic properties, where P_1 genotype produced highest yield attributes that also may be due to the highest absorbed sunlight and flowed CO_2 into canopy (Emam and Eikaee, 2002), increasing chlorophyll formation (Table 6) and consequently the increase in photosynthesis, forming more photosynthetic matters that transform to yielding parts and increasing all yield attributes. The increase in oil and protein yields in P_1 genotype plants and D_3 treatments may be attributed to the increase in seed number of pods and seed yield per plant/hectare (Tables 4 and 5). It was also reported that the oil content of canola plants significantly influences by genetic factors in addition to environmental factor (Ozoni Davaji et al., 2007). The highest protein content obtained with P_1 genotype plants and D_3 treatments may be attributed the reduction of hydrocarbonal matters to proteins (Bahrani and Babaei, 2007).

Data of leaf photosynthetic pigments (chlorophylls and carotenoids) are presented in Table 6. Chlorophyll-a and total chlorophylls showed significant ($P \leq 0.05$) increases with P_1 (35/9) compared to all other genotypes (P_2, P_3 and P_4). The treatment of D_3 (15 cm between rows and the planting in both rage sides) also showed significant increases ($P \leq 0.05$) for the same parameters. The interactions between genotypes and plant population densities are significant ($P \leq 0.05$) for only chlorophyll-a, but are non-significant for

the other pigments. The plant leaves of P_1 genotype and of D_3 treatment showed highest chlorophylls compared to all other genotypes and plant population densities, leading to increasing the photosynthetic efficiency of leaves and consequently increasing the photosynthetic matters that be employed in favor of plant growth (Table 4) and yield attributes (Tables 4 and 5).

Conclusion

Results of this study indicate that there are significant differences in all growth and yield attributes among all used genotypes and also among all tested plant population densities. The P_1 genotype planted at the population density of 222 222 plant per hectare is the optimum cultivation strategy recommended to obtain the highest growth traits, producing the highest yield attributes.

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Table (1): Physical and chemical properties of the experimental soil.

Component	2010/2011 season	2011/2012 season
Particle size distributions %		
Sand	81.6	81.3
Silt	5.8	5.9
Clay	12.6	12.8
Soil texture class	Loamy sand	Loamy sand
Chemical analysis		
pH soil paste	7.98	7.73
ECe (dSm) in soil paste	4.72	4.21
Organic matter %	1.11	1.27
Available N (%)	0.05	0.06
Available P (ppm)	3.69	3.98
Available K (ppm)	159	183

Table (2): Origin and pedigree of the four canola genotypes

Name	Pedigree	Origin
P1 (35/9)	C103/SIDO*2C103 9C-6SU-1SU-13SW-2SW0SW	Egypt
P2 (26/18)	18C-21SU-4SW-15SW-1SW	Egypt
P3 (Drakkar)	Variety	Germany
P4 (Hanna)	Variety	Germany

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Journal of Biotechnological Sciences
ISSN: 2308-0043

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Table 3 Mean squares of ordinary analysis for plant density, canola genotypes and their interaction with all studied traits in both cultivated seasons.

SOV[a]	Plant height (cm)	Height of the 1st branch (cm)	No. of branches / plant	No. of siliquas/ Plant	Seed yield/ plant (g)	Biological yield ha^{-1} (t)	Seed yield ha^{-1} (t)	Oil yield ha^{-1} (t)	Protein yield ha^{-1} (t)	1000 seed weight (g)
2010/2011 season										
Genotypes (P)	659.2*	274.9*	5.11*	14042.8*	12.78**	29.72*	2.97**	0.66**	0.33**	1.08*
Error (a)	130.3	51.8	1.01	2604.0	0.61	3.91	0.18	0.04	0.02	0.12
Density (D)	978.8**	202.4*	7.41**	21889.4*	37.95**	15.89**	2.93**	0.61**	0.25**	1.09**
PxD	48.8*	54.4^{ns}	0.98^{ns}	1364.9*	1.28*	2.52^{ns}	0.20^{ns}	0.05^{ns}	0.02^{ns}	0.37*
Error (b)	9.53	45.1	0.57	452.2	0.43	2.45	0.14	0.03	0.01	0.13
2011/2012 season										
Genotypes (P)	640.2*	248.3*	8.43*	9451.9*	14.76**	22.7^{ns}	2.75**	0.59*	0.29**	1.44*
Error (a)	100.2	38.0	1.75	1874.2	1.09	7.24	0.44	0.09	0.02	0.15
Density (D)	1359.7*	155.2**	12.66*	22173.5*	42.31**	22.33*	1.41**	0.32**	0.14**	1.73**
PxD	83.1*	73.1^{ns}	1.87**	1434.9*	1.94*	2.95^{ns}	0.25^{ns}	0.05^{ns}	0.03*	0.25*
Error (b)	27.93	21.14	0.37	371.7	0.51	5.35	0.15	0.03	0.01	0.08

* Significant at 0.05 levels of probability. ** Significant at 0.01 levels of probability. [a] SOV = Source of variance.

Table (4): Effect of plant distribution systems on some canola genotype traits in 2010/2011 and 2011/2012 seasons

	Treatment	Plant height (cm)	Height of the 1st branch (cm)	No. of branches / plant	No. of siliquas/ Plant	Seed yield/ plant (g)
2010/2011 season						
Genotypes (P)	P_1	122.38	25.86	7.33	218.61	8.57
	P_2	109.04	27.18	5.84	171.23	7.46
	P_3	101.90	38.16	5.69	123.04	5.82
	P_4	113.32	31.17	6.02	158.62	6.52
	LSD_a	**13.17***	**8.30***	**1.16***	**49.94***	**0.90****
Densities (D)	D_1	119.81	34.48	5.48	123.20	5.21
	D_2	101.95	31.00	6.15	172.16	7.32
	D_3	113.23	26.29	7.04	208.28	8.75
	LSD_b	**2.67****	**5.81***	**0.65****	**16.69****	**0.57****
	G × D	**5.34****	**NS**	**NS**	**33.37***	**1.14***
2011/2012 season						
Genotypes (P)	P_1	123.54	23.90	7.51	207.41	8.28
	P_2	110.99	26.67	5.40	171.81	7.36
	P_3	103.07	36.11	5.52	129.24	5.44
	P_4	112.10	29.90	6.14	158.66	6.07
	LSD_a	**11.55***	**7.11***	**1.53***	**58.86***	**1.20****
Densities (D)	D_1	122.23	31.98	5.06	121.69	4.74
	D_2	101.10	30.35	6.28	171.34	7.21
	D_3	113.95	25.10	7.10	207.31	8.42
	LSD_b	**4.57****	**3.98****	**0.53****	**18.40****	**0.62****
	G× D	**9.15****	**7.96***	**1.05****	**36.81***	**1.24***

Ns,*, and**= Not significant, significant at <0.05 and <0.01, respectively.

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Journal of Biotechnological Sciences
ISSN: 2308-0043

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Table (5): Effect of plant distribution systems on some canola genotype traits in 2010/2011 and 2011/2012 seasons

Treatment		Biological yield ha^{-1} (t)	Seed yield ha^{-1} (t)	Oil yield ha^{-1} (t)	Protein yield ha^{-1} (t)	1000 seed weight (g)	Oil %	Protein %
2010/2011 season								
Genotypes (P)	P_1	10.92	2.84	1.25	0.81	3.60	43.88	28.39
	P_2	7.40	2.43	1.05	0.65	3.10	42.90	26.79
	P_3	6.82	1.48	0.60	0.35	2.82	40.70	23.69
	P_4	8.17	2.18	0.92	0.57	2.92	42.31	26.38
LSD_a		**2.28***	**0.49****	**0.24****	**0.16****	**0.40***	**1.57***	**2.83***
Densities (D)	D_1	9.42	2.44	1.05	0.64	2.77	42.48	25.64
	D_2	7.13	1.67	0.70	0.44	3.33	41.93	25.96
	D_3	8.43	2.58	1.12	0.72	3.24	42.93	27.33
LSD_b		**1.35****	**0.33****	**0.14****	**0.10****	**0.32****	**NS**	**0.86****
P × D		**NS**	**NS**	**NS**	**NS**	**0.63***	**NS**	**1.72***
2011/2012 season								
Genotypes (P)	P_1	9.96	2.68	1.18	0.76	3.54	43.69	28.26
	P_2	7.87	2.34	1.00	0.63	3.19	42.79	27.26
	P_3	6.09	1.38	0.56	0.34	2.59	40.94	24.43
	P_4	7.64	2.25	0.95	0.59	2.98	42.28	26.51
LSD_a		**NS**	**0.77***	**0.34***	**0.18****	**0.45***	**1.34***	**2.19***
Densities (D)	D_1	8.84	2.11	0.89	0.55	2.70	41.98	26.13
	D_2	6.33	1.85	0.78	0.49	3.46	42.01	26.30
	D_3	8.51	2.53	1.10	0.70	3.06	43.28	27.41
LSD_b		**2.00***	**0.34****	**0.15****	**0.09****	**0.24****	**NS**	**NS**
G× D		**NS**	**NS**	**NS**	**0.18***	**0.48***	**NS**	**NS**

Ns,*, and**= Not significant, significant at <0.05 and <0.01, respectively.

Journal of Biotechnological Sciences
ISSN: 2308-0043

Table (6): Effect of plant distribution systems on some canola genotype traits in 2011/2012 season.

Treatment		chloro A	cloro B	cloro T	caroten
		2011/2012 season			
Genotypes (P)	P_1	1.93	0.78	2.75	0.69
	P_2	1.55	0.98	2.57	0.71
	P_3	1.28	0.85	2.16	0.98
	P_4	1.35	0.98	2.37	0.76
	LSD_a	**o.38**	**NS**	0.38*	**NS**
Densities (D)	D_1	1.40	0.89	2.32	0.74
	D_2	1.45	1.04	2.52	0.82
	D_3	1.73	0.78	2.54	0.77
	LSD_b	**0.25***	**NS**	**NS**	**NS**
	P × D	**0.49***	**NS**	**NS**	**NS**

Ns,*, and**= Not significant, significant at <0.05 and <0.01, respectively.